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The relationship between self-concept and achievement in TIMSS 2007: A comparison between American and Japanese students

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Abstract The purpose of this research was to investigate the relationship between eighth-grade students' maths-related self-concepts and their achievements in the Trends in International Mathematics and Science Study (TIMSS) 2007. The students' maths self-concept was compared with other variables, namely their mothers' education, their fathers' education and the amount of books held in the students' households. To investigate the potential role of culture, a comparison between American and Japanese students' scores was also included. The findings demonstrated that students' maths self-concept was positively associated with their achievement both in the United States and Japan, but Japanese students, while having higher achievement, had a lower maths self-concept than American students. Maternal education, paternal education and the number of books at home were also found to be positively related to achievement. Examining standardised coefficients, the study confirmed a strong interaction between maths self-concept and country, as well as a positive connection between maths self-concept as such (irrespective of the country) with maths achievement.

Keywords Maths self-concept · Achievement · Cultural differences · Race · Ethnicity · Gender

Résumé Relation entre auto-évaluation et résultats de l'étude TIMSS 2007 : comparaison entre élèves américains et japonais – Ce travail de recherche avait pour objectif d'examiner la relation entre l'auto-appréciation en mathématiques d'élèves de huitième classe, et leurs niveaux établis par l'étude des tendances internationales en sciences et mathématiques (Trends in International Mathematics and Science Study, TIMSS) de 2007. Cette auto-appréciation a été comparée à d'autres variables, à savoir le niveau d'études des mères, celui des pères et le nombre de livres

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présents dans le foyer. Pour analyser l'influence éventuelle de la culture, il a été en outre procédé à une comparaison entre les notes des élèves américains et japonais. Les résultats révèlent que, tant aux États-Unis qu'au Japon, l'auto-appréciation est proportionnelle aux niveaux obtenus. Néanmoins, l'auto-évaluation des élèves japonais est inférieure à celle des élèves américains, même s'ils atteignent des niveaux supérieurs. Le niveau de formation des mères et des pères ainsi que le nombre de livres existant dans le foyer s'avèrent également être des facteurs favorables aux résultats. À l'examen des coefficients standardisés, l'étude confirme une forte interaction entre l'auto-évaluation dans cette matière et le pays, ainsi qu'un rapport positif entre l'auto-appréciation appréhendée isolément (indépendamment du pays) et les résultats en mathématiques.

Zusammenfassung Selbsteinschätzung und Leistung in der TIMSS 2007: ein Vergleich zwischen amerikanischen und japanischen Schulkindern – Zweck dieser Forschungsarbeit war die Untersuchung des Zusammenhangs zwischen der Selbsteinschätzung der Schülerinnen und Schüler der Jahrgangsstufe acht und ihren Leistungen im Rahmen der Trends in International Mathematics and Science Study (TIMSS = Internationale Mathematik- und Naturwissenschaftsstudie) 2007. Die Selbsteinschätzung der Schülerinnen und Schüler im Fach Mathematik wurde mit anderen Variablen verglichen, nämlich mit dem Bildungsgrad der Mutter, dem Bildungsgrad des Vaters und der Zahl der Bücher, die im Elternhaus der Schülerinnen und Schüler vorhanden waren. Um zu untersuchen, welche Rolle die Kultur dabei möglicherweise spielt, wurde auch ein Vergleich zwischen den Noten amerikanischer und japanischer Schülerinnen und Schüler angestellt. Es stellte sich heraus, dass die Selbsteinschätzung der Schülerinnen und Schüler im Fach Mathematik sowohl in den Vereinigten Staaten als auch in Japan positiv mit ihren Leistungen korreliert. Jedoch war die Selbsteinschätzung der japanischen Schulkinder, trotz besserer Leistungen, schlechter als die der amerikanischen Schulkinder. Eine positive Korrelation mit den Leistungen ergab sich auch für den Bildungsgrad der Mutter, den Bildungsgrad des Vaters und die Zahl der Bücher im Elternhaus. Die Untersuchung standardisierter Koeffizienten in der Studie ergab eine deutliche Wechselwirkung zwischen der Selbsteinschätzung im Fach Mathematik und dem Land sowie einen positiven Zusammenhang zwischen der Selbsteinschätzung im Fach Mathematik generell (ohne Berücksichtigung des Landes) und den mathematischen Leistungen.

Resumen Relación entre autoconcepto y rendimiento en TIMSS 2007: comparación entre estudiantes estadounidenses y japoneses – El objetivo de este estudio ha sido investigar la relación que existe entre los autoconceptos en matemáticas de estudiantes de octavo grado y sus rendimientos en el Estudio Internacional de Tendencias en Matemáticas y Ciencias (TIMSS) 2007. Los autoconceptos de los estudiantes se compararon con otras variables; a saber, nivel de educación de sus madres, nivel de educación de sus padres y cantidad de libros que se encuentran en los hogares de los estudiantes. Con el fin de investigar el papel potencial de la cultura, también se realizó una comparación entre los puntajes de los estudiantes estadounidenses y japoneses. Los resultados demostraron que el autoconcepto en

matemáticas de los estudiantes tenía una relación positiva con sus rendimientos, tanto en los Estados Unidos como en Japón, pero que los estudiantes japoneses, si bien tenían un rendimiento más alto, también tenían un autoconcepto en matemáticas más bajo que los estudiantes estadounidenses. La educación materna, la educación paterna y el número de libros disponibles en el hogar también guardan una relación positiva con el rendimiento, según se ha comprobado. Examinando coeficientes estandarizados, el estudio confirmó que hay una fuerte interacción entre el autoconcepto en matemáticas y el país, así como hay una conexión positiva entre el autoconcepto en matemáticas como tal (independientemente del país en cuestión) y el rendimiento en matemáticas.

Резюме Взаимосвязь между концепциями и достижениями в TIMSS 2007: сравнение между американскими и японскими учащимися – Целью данного исследования было определить взаимосвязь между математическими концепциями учащихся восьмых классов и их достижениями согласно Тенденциям международных исследований по математике и науке (TIMSS) 2007 года. Математическая концепция учащихся сравнивалась с другими переменными, а именно уровнем образования их матерей, отцов и количеством книг в доме учащегося. Для того чтобы оценить потенциальную роль культуры сравнение проводилось между американскими и японскими учащимися. Полученные данные показали, что математическая концепция учащихся была позитивно связана с их достижениями, как в США, так и в Японии, но у японских учащихся, имеющих более высокие показатели, математическая концепция была более низкой, чем у американских учащихся. Образование матери, отца и количество книг в доме оказывали также положительное влияние на достижения. Данное исследование, используя стандартизированные коэффициенты, подтверждает, что имеется сильное взаимодействие между математической концепцией и страной, а также позитивная связь между математической концепцией как таковой (независимо от страны) и достижениями по математике.

Numerous studies have found a positive relationship between academic self-concept and test scores (Marsh 1986; Marsh and Hau 2004). As Herbert W. Marsh and Kit-Tai Hau (2004) discussed, self-concept influences a wide variety of fields such as social psychology, personality, education, child development, mental and physical health, social services, organisation, industry and support. Richard J. Shavelson (Shavelson et al. 1976) refined his self-concept model based on the multidimensionality and hierarchical structure of self-concept. Before Shavelson, self-concept was treated as one dimension, but his model placed academic and non-academic self-concept under general self-concept.

Herbert W. Marsh (1986) built on Shavelson's idea that academic achievement in a specific discipline raises academic self-concept in the discipline. Marsh's study was important because he was the first researcher to differentiate between external

and internal comparison. With external comparison, students assess their academic abilities by comparing other people's test scores with their own. For example, students think they are good at maths if their maths scores are higher than other students' maths scores. By contrast, in internal comparison students use their own test scores to assess their academic abilities. For example, students compare their own maths scores with their own English scores and think they are good at maths if their own maths scores are higher than their own English scores. Marsh proposed the internal/external (I/E) model to explain that both internal as well as external comparisons affect academic self-concept.

To test the I/E model, Marsh investigated English and maths self-concepts of people aged 7 to 35. He invented Self Description Questionnaires (SDQ) to examine academic self-concept. In addition, he explored the relationship between these self-concepts and actual academic achievement. To examine age differences, he compared three different age groups: preadolescents, high school students, and adults including university students. Consequently, Marsh found that there were hardly zero correlations between verbal and maths self-concepts, whereas there were substantial correlations between verbal and maths achievement. As for gender differences, females' academic self-concept was lower than males'. This pattern was seen across different age groups.

Marsh pointed out that the opinions of teachers and peers were unlikely to affect one's self-concept because one's internal comparison is more influential than the feedback of others. In particular, if students attend a school where the average students' achievement is high, they tend to devalue their achievement even though their test scores are above average on a national level. Overall, Marsh recognised the internal and external comparisons and their effects, though he could not confirm their universality because the research was not cross-cultural.

Barbara M. Byrne and Darlene A. Worth Gavin (1996) used Marsh's SDQ and compared three age groups (grades 3, 7 and 11) to investigate the developmental stage of the relationship between students' maths and English self-concepts and their achievements in these subjects. Byrne and Gavin questioned whether academic achievement raises general self-concept. Based on their findings, Byrne and Gavin supported both Shavelson's and Marsh's idea that self-concept is not one-dimensional but can be divided into general self-concept and academic self-concept. However, they did not see how these two self-concepts affect each other or discern any particular pattern in the relationship between students' academic self-concept, their achievement and their age. Thus, their results conflict with Marsh's research (1990), which found that academic achievement can raise general self-concept, and that this structure deteriorates as a child gets older. In contrast, Byrne and Gavin found a reciprocal relationship between academic self-concept and achievement.

Marsh and Hau (2004) took a new approach towards self-concept research by conducting a cross-cultural study to examine whether the I/E model could be universally adopted. Following Shavelson's model, Marsh and Hau tried to verify the multi-dimensional aspect of self-concept by focusing specifically on academic self-concept rather than on general self-concept. They supposed that academic self-concept is a better predictor of academic performance. Furthermore, Marsh and Hau

divided academic self-concept into verbal and maths self-concepts, and examined how each correlates with maths and verbal achievement. In order to obtain international data, they used the Programme for International Student Assessment (PISA) project designed by the Organisation for Economic Co-operation and Development (OECD).

Fifteen-year-olds from 26 countries provided the data for Marsh and Hau's research. Marsh and Hau found a positive correlation between maths achievement and maths self-concept, as well as a positive correlation between reading achievement and verbal self-concept. However, the correlation between reading achievement and maths self-concept as well as the correlation between maths achievement and verbal self-concept were both negative. Additionally, the correlation between the two self-concepts was low ($r = .10$), although there is a strong correlation between maths and verbal achievement ($r = .78$). Furthermore, by using multi-group confirmatory factor analyses (CFAs)[1] to work on cross-cultural comparison, Marsh and Hau confirmed that the result supported the I/E model and its possibility of international adaptation.

Using the PISA study, Marsh and Hau supported Marsh's past research (Marsh 1986) on the I/E model on an international level. However, as Marsh and Hau mentioned, the result of the research does not entirely justify a generalisation of the I/E model because only three (Brazil, Mexico and Korea) out of twenty-six participating countries were non-western countries. Thus their study has a limitation to its generalisation.

Mei-Shiu Chiu's (2008) study is important because of her application of Marsh's I/E model (1986), which he used to investigate maths and verbal self-concepts, to the comparison between a maths self-concept and a science self-concept. Chiu focused on the multidimensional aspect of self-concept and its effect on academic achievement. The sample population of Chiu's research was eighth-grade students who had participated in a TIMSS 2003 study of 28 countries. Chiu used structural equation modelling (SEM) as a research method and conducted analysis single-level, multilevel and multi-group level analyses. Multilevel analysis examines students, classes and countries, and multi-group analysis works on cultural comparison.

The results of the single- and multi-level analyses established three points: (1) there is a positive path from maths achievement to maths self-concept and from science achievement to science self-concept; (2) there are negative paths from maths achievement to science self-concept and from science achievement to maths self-concept; (3) there are strong correlations between maths and science achievement. Thus, according to Chiu, the finding supports the I/E model. However, the researcher pointed out that the way maths and science are treated influences the correlation of self-concept on the two subjects; in some countries, the two subjects are treated separately as different subjects, whereas other countries treat them as continuous subjects. The weak points of this study, Chiu suggested, were first that there was a limitation to examining the reciprocal and causal relations between the maths and science self-concepts and achievements. Second, a

[1] A multi-group confirmatory factor analysis is a method for measuring factor invariance.

negatively-worded item corrupted the accuracy of the measurement on the cross-cultural research.

Jesse L. M. Wilkins' (2004) study differentiated self-concept by the individual and by geographic region. Wilkins studied the self-concept of students who participated in TIMSS 1995 and questioned the relationship between self-concept and achievement. To investigate this relationship, Wilkins looked at the data on the individual level as well as the country level, considering the geographic region. Most of the participants of Wilkins' study sample were 13 years old. To examine self-concept, Wilkins focused on the items "I usually do well in mathematics" and "I usually do well in science", which were answered by students choosing one option out of four: 1 for strongly disagree, 2 for disagree, 3 for agree, 4 for strongly agree. The researcher also coded Middle Eastern, Western European, North and South American and Australasian countries as 1 and Asian and Eastern European countries as 0 to investigate geographic influence based on Edward W. Kifer's (2002) research.

At the individual level, Wilkins found there was a strong positive correlation between student self-concept and maths and science achievement, and it was statistically significant. Science self-concept had a positive correlation with achievement, but it is negligible due to the weak correlation. At the country level, the correlation was negative. That is, countries which showed markedly higher self-concepts had lower achievement and vice versa. In particular, Denmark, Israel and Kuwait were the three highest-ranking countries in maths self-concept, and Japan, Korea and Hong Kong were the three lowest-ranking countries. On the other hand, Iran, Colombia and Kuwait were the three highest-ranking countries on science self-concept, whereas Hong Kong, Japan and Korea were the three lowest-ranking countries. In terms of geographic region, Wilkins pointed out that Asian and East European students tended to have a lower self-concept than students in Middle Eastern, Western European, North and South American and Australasian countries. Wilkins's findings showed that maths and science self-concepts were embedded in culture, and academic achievement was not necessarily associated with the level of self-concept.

Ce Shen and Hak Ping Tam (2008) also compared the individual and country levels to examine the relationship between academic self-concept and achievement. They argued that research on a cross-national level can shed new light on academic self-concept research, which is different from the individual level. Shen and Tam based their research on TIMSS 1995, 1999 and 2003, and took eighth-graders as their population sample. To look at self-concept, they used three questions: (1) I like maths/science; (2) I usually do well in maths/science; (3) I learn things quickly in maths/science. The first and third questions examine the subject's self-perception while the second question examines self-efficacy. The researchers calculated the correlation between the answers to each question and the test scores.

Shen and Tam found that, on the individual level, students who scored higher for the three questions tended to perform better than those who scored lower. In cross-national research, on the other hand, the researchers found a negative correlation between students' performance and the answers to these three questions. That is, students from high-performing countries were likely to think

they did not like or enjoy maths and science. Also, they tended to believe they did not learn these subjects quickly whereas students in low-performing countries did. Asian countries such as Japan, Korea and Taiwan represented the former case and African countries such as Ghana and South Africa represented the latter case. Shen and Tam argued that a country's curriculum as well as cultural and social contexts influenced the result. For example, high-performing countries have demanding curricula, so students tend to think it is challenging to keep up with the class on a national level whereas students in low-performing countries do not (Shen and Tam 2008, p. 97).

By using the data from the TIMSS studies, Shen and Tam found differences between individual and country levels regarding the relationship between maths and science self-concept and students' achievement. Based on the differences between these two levels, they suggested that culture can affect the correlation between self-concept and achievement. Shen and Tam also distinguish themselves from other researchers in describing how cultural expectation might influence the relationship between academic self-concept and academic performance.

Through extensive examination of past research, Xin Ma and Nand Kishor (1997) confirmed the positive correlation between academic self-concept and achievement. Ma and Kishor reviewed 143 articles and coded them to examine the relationship between self-concept, the perception of family support, the perception of gender roles in maths, and achievement in maths. Overall, they uncovered that academic achievement in a specific discipline is positively associated with academic self-concept in the same discipline. The perception of family support and the perception of maths as a male domain were also positively correlated with academic achievement.

Ma and Kishor concluded that gender differences did not influence the relationship between maths achievement and maths self-concept, the perception of family support and the perception of maths as a male domain. They pointed out that there were age differences, and the time spent at junior high school was particularly important for the relationship between self-concept and achievement. The relationship was strengthened by 54 per cent from upper elementary grades to junior high grades, then decreased by 70 per cent from junior high to senior high grades. The correlation between the perception of family support and academic achievement also increased by 45 per cent from elementary school to junior high school and decreased by 68 per cent from junior high to senior high grades. In terms of ethnicity, Ma and Kishor concluded that the academic self-concept-achievement relationship was significantly stronger for Whites and Asians than for Blacks and other ethnic groups.

The existing studies by the aforementioned researchers demonstrated the correlation between academic self-concept and achievement. In the current study, the relationship between Japanese and American[2] students' maths self-concept and their academic achievement in maths was investigated. This study also examined which was the strongest predictor of students' maths achievement – maternal education, paternal education, total number of books in the students' household or

[2] In this study, the terms "America" and "American" refer to the United States of America.

cultural background in terms of Japanese and American students' maths self-concept. Working on these research questions is potentially important because while how one perceives one's academic ability is mostly invisible, it could in fact be a considerable contributor to tangible performance and achievement. It is also feasible for an instructor to work on improving a student's self-concept through his or her teaching method. For example, an instructor could gradually make sure to give students problem-solving tasks in which he or she moves from easy to challenging steps.

Method

Data source and sample

For the present study, TIMSS 2007 was used as the data source. TIMSS 2007 was the fourth international mathematics and science educational research organised by the International Association for the Evaluation of Educational Achievement (IEA). Fifty-nine countries and eight regional entities participated in this study. TIMSS collected the data from students in fourth and eighth grades, and in total, there were 183,150 fourth-grade participants and 241,613 eighth-grade participants. The dataset given by TIMSS 2007 was useful in the examination of the research questions for the following three reasons. First, the data were collected internationally from a large sampling population. Second, TIMSS designed a "two-stage stratified probability sampling" (Wilkins 2004, p. 333) to select schools and students, and the process of random sampling was carefully conducted. Third, TIMSS 2007 asked participants about their backgrounds and attitude toward learning.

In the present research, the targeted population was eighth graders from the United States and Japan. The participants of this study were 7,377 American students (female: 3,697; male: 3,622; gender information missing: 58) and 4,312 Japanese students (female: 2,128 male: 2,158, gender information missing; 26). The average age of the American sample was 14.4 years ($SD = .56$) and the average age of students in the Japanese sample was 14.77 years ($SD = .42$).

In TIMSS 2007, both U.S. and Japanese national scores were above the international average in terms of test scores (Mullis et al. 2008), the Japanese score being higher ($M = 571.01$, $SD = 85.11$) than the American score ($M = 506.12$, $SD = 76.77$). According to the TIMSS 2007 report, mathematics assessment consisted of content and cognitive domains. In eighth grade, numbers, algebra, geometry, data and chance belonged to the content domain, whereas knowing, applying and reasoning were assessed in the cognitive domain (Mullis et al. 2008). There was an achievement gap between Japan and the U.S., and the American score was lower than the Japanese score both in the content and cognitive domains.

Japan and the U.S. are comparable in terms of the relationship between maths self-concept and maths achievement due to their relatively similar country development level. According to a report about Gross Domestic Product (GDP) by the Organisation for Economic Co-operation and Development (OECD) in 2007, the United States per capita GDP was US$ 13,741.6 and ranked first and Japanese

per capita GDP was US$ 4,295.9 and ranked third. The Human Development Index (HDI), an indicator calculated by the United Nations Development Programme (UNDP) accounted for various social factors such as a country's education level, life expectancy and GDP. According to the *Human Development Report* (2009), the Japanese and the American HDI in 2007 were .96 and .956 respectively, and the two countries were categorised as having "very high human development". The data show that, as a country is more developed, students are likely to attain higher achievement (Mullis and Martin 2007), and it is inevitable to consider social factors when comparing students from countries which have contrastive development statuses. When comparing American with Japanese students, on the other hand, economy and other social components may be considered less important because the development levels of these two countries are relatively close. By comparing American and Japanese students, one can focus on cultural differences in self-concept and how students' self-concept is related to their achievement level.

Instruments

To address the research questions, the following items were selected from the TIMSS questionnaire about students' background: (1) students' maths self-concept, (2) education of students' mothers, (3) education of students' fathers, (4) the number of books that students have in their house. The dependent variable was students' mathematical achievement. To assess achievement, the variable labelled BSMMAT01 was taken instead of students' test scores. TIMSS 2007 prepared 14 types of booklets and point systems were different depending on the booklet. Thus the raw scores from different booklets were not comparable. According to the TIMSS 2007 user guide, the best way to measure students' achievement is BSMMAT01, which is one of the five plausible variables: "The plausible values for any given scale are the best available measures of student achievement on that scale in the TIMSS 2007 international database, and should be used as the outcome measure in any study of student achievement" (Foy and Olson 2009, p. 89). TIMSS 2007 had five plausible variables, each of which equally explained participants' achievement. Hence only one out of five plausible variables, the one labelled BSMMAT01, was used as a dependent variable. The scale of the plausible variable was from 0 to 1,000, while the mean score was set at 500 with a standard deviation of 100.

Students' maths self-concept score consisted of the following eight items prepared by TIMSS 2007:

(1) I enjoy learning maths;
(2) Maths is boring;
(3) I like maths;
(4) I usually do well in maths;
(5) I would like to take more maths classes;
(6) Maths is more difficult for me;
(7) Maths is not one of my strengths;
(8) I learn things quickly in maths.

A four-point scale was used for all items (1 = agree a lot, 2 = agree a little 3 = disagree a little 4 = disagree a lot), but the items which had positive sentences were recoded to combine with other items with negative sentences to adjust the meanings. Cronbach's alpha was .88 in the American data and .86 in the Japanese data. Cronbach's alpha measures how items are closely related each other, and these results suggested that there was sufficient internal consistency to combine the eight items in both data sets. The new scale for the combined maths self-concept variable was 8 to 32.

Although the ranges of the original scales were different, American and Japanese items, which measured education of a student's mother and father, were adjusted to compare the two countries. As a result, a student whose mother's or father's education was below high school level was coded 1; high school diploma level was coded 2; college education level, including associate level, was coded 3; and above master's degree level was coded 4.

American and Japanese scales for the item that measured the number of books a student had at home were the same, so no adjustment was needed for this item. The scale of this item is from one to five. However, the number of books does not increase equally as a code number increases.. For example, a student who had up to 10 books was coded 1, while a student who had 26 to 100 books was coded 3. However, a larger coded number indicated that a student had more books in his or her home.

Statistical analysis

Gender and age differences in students' achievement levels were examined by doing a *t*-test[3] and an analysis of variance (ANOVA)[4] respectively. Also, the two-way ANOVA was used when the two countries showed different directions by gender within the same variable. Racial differences were also examined by conducting regression as well as ANOVA on only the American sample. The Japanese sample did not provide information about participants' ethnicities.

Next, the following steps were taken to address the main research questions. First, the raw data of American and Japanese students were merged. American students were dummy-coded as 0 and Japanese students dummy-coded as 1. Second, the interaction between self-concept and country was calculated. Third, multiple regression analysis was conducted using students' achievement scores as a dependent variable and the following six variables as independent variables: (1) self-concept, (2) country, (3) interaction between self-concept and country, (4) mother's education, (5) father's education and (6) the number of books that students have in their household. It was appropriate to use them as independent variables because they were correlated with each other and presumably had causal effects on the dependent variable (Allison 1999). Gender differences as well as country differences were examined by splitting the sample by gender and country

[3] A *t*-test is a statistical test to see if there is a significant difference between two different groups' means.

[4] An analysis of variance (ANOVA) is a statistical analysis to see the degree of difference between two or more groups' data, using their means.

Table 1 Description of population of American students' ethnicities and their mean scores of achievement

Ethnicities	Population	Per cent	Mean scores of achievement	Mean maths self-concept
White	3,873	52.5	532.79	21.76
Black	949	12.9	454.07	22.44
Hispanic	1,787	24.2	471.56	20.98
Asian	243	3.3	549.33	24.17
Native American	90	1.2	486.84	22.34
Pacific Islander	58	.8	507.89	22.88
Two or more races	282	3.8	502.56	21.74
Missing*	95	1.3		
Total	7,377	100%	506.12 (average)	21.74 (average)

Source Data selected from *TIMSS 2007 International mathematics report* (Mullis et al. 2008) for the purposes of this study

* Missing refers to no answer from TIMSS 2007 participants

respectively. By applying the same multiple regression model, racial differences were also explored in the American sample using ANOVAs. As Table 1 shows, the American sample consisted of White ($n = 3{,}873$), Black ($n = 949$), Hispanic ($n = 1{,}787$), Asian ($n = 243$), Native American ($n = 90$), Pacific Islander ($n = 58$) and racially mixed ($n = 282$) students.

Results

Gender, age and racial differences

The results of the *t*-test confirmed gender differences in students' maths achievement, $t(11585.6) = 3.26$, $p = .001$, with males having higher scores than females. Age differences were found by ANOVA, $F(6, 11598) = 74.74$, $p < .01$. The American and Japanese samples showed different directions in the relationship between gender and the number of books; thus the two-way ANOVA was conducted. As a result, the interaction was confirmed, $F(1, 11535) = 67.71$, $p < .01$, which revealed that Japanese female students were likely to read fewer books than Japanese male students, but American female students were likely to read more books than American male students.

An achievement gap among different races was found in the American sample. Comparing the mean achievement scores, Asian students had the highest mean scores followed by White, Pacific Islander, mixed-race, Native American, Hispanic and Black students. The ANOVA results revealed that the American students' maths achievement scores differed significantly by race and ethnicity, $F(6, 7275) = 277.08$, $p < .01$. The mean scores of Native American, Hispanic and Black students were below the international average, while students of other racial groups achieved scores higher than the international average. Comparing different ethnic groups of American

students, their achievement was not found to correlate with their maths self-concept scores. Asian students had the highest self-concept score followed by Black, Native American, Pacific Islander, White and mixed-race students.

The relationship between maths self-concept and achievement

Table 2 shows the results of a multiple regression analysis in which students' achievement was found to regress in relation to their maths self-concept, mothers' education, fathers' education and the number of books at home. The sample included American and Japanese students. Based on these results, a statistically significant positive relationship between self-concept and achievement in the two countries was confirmed: $b = 3.8$, $t(7192) = 22.81$, $p < .01$. Additionally, the interaction between maths self-concept scores and nationality was statistically significant: $b = 2.73$, $t(7192) = 8.82$, $p < .01$. That is, different effects of self-concept and nationality were found. Since Japanese students were coded as 1 and American students were coded as 0, a positive coefficient of the interaction between self-concept and country meant that Japanese students were likely to have a lower self-concept than American students, even if the students from the two countries had the same level of achievement. The interaction indicated that the slope of Japanese students' self-concept was 2.72 points higher than the slope of American students' self-concept. Theoretically, while American students' achievement increased by 3.8 points for each unit of increase in their maths self-concept, Japanese students' achievement increased 6.52 points for each unit of change in their maths self-concept if there was no effect from other independent variables. The 2.72 point gap originated in the interaction between maths self-concept and country. Due to the interaction between maths self-concept and country, the slope of the Japanese

Table 2 Effect of eighth-grade students' maths self-concept, country, mothers' education, fathers' education and number of books at home on students' achievement scores in maths (American and Japanese samples combined)

Independent variables	Unstandardised regression coefficient	Standard error	Standardised regression coefficient	*t* Value
Maths self-concept	3.80**	.17	.26	22.81
Country (Japan = 1) (U.S. = 0)	28.45**	6.23	.16	4.57
Interaction between country and maths self-concept	2.73**	.31	.30	8.82
Mothers' education	6.77**	1.19	.07	5.71
Fathers' education	14.26**	1.15	.15	12.38
Books	14.31**	.66	.22	21.67
N	7,199			
R^2	.39			

** $p < .01$

Source Data selected from *TIMSS 2007 International mathematics report* (Mullis et al. 2008) for the purposes of this study

students' maths self-concept variable was steeper than the American students' slope. This interaction means that the difference between Japanese and American achievement grew as the unit of maths self-concept increased.

In addition, the results from the regression analysis showed the positive relations of mothers' education, fathers' education and the number of books at home on students' maths achievement scores. All the coefficients were statistically significant at the .01 level. The coefficient of the country variable was positive because Japanese students' scores on maths were likely to be higher than American students' scores. R squared[5] was .39, which meant about 39 per cent of the variability in students' maths achievement scores was explained by this regression line.

The coefficient of the country variable was 28.45, which indicated an achievement gap between Japanese and Americans if there was no effect from other variables. That is, even if Japanese and Americans' value of maths self-concept is 0, Japanese typically should have 28.45 points more in their achievement. The coefficient of the mothers' and fathers' education indicated that in the U.S.–Japan combined sample one unit increase of mothers' and fathers' education was positively related to 6.77 and 14.26 point changes in students' achievement respectively if the other variables' coefficients were zero. The coefficient of the books variable was 14.31, which suggested that one unit increase of the books' variable was linked to a 14.31 point increase in students' achievement, other variables being held constant.

Looking at the standardised coefficients, the interaction between maths self-concept and country had the greatest impact on students' achievement among all the variables, while maths self-concept was second, followed by the number of books that a student had at their home, country, mothers' education and fathers' education. Although the mother's education, father's education and books variables had larger unstandardised coefficients, a standardised coefficient demonstrated that the relationship between country and maths self-concept as well as maths self-concept itself had a larger effect in a standardised scale. Additionally, it should be noted that the standardised coefficient of the books variable was connected to students' achievement more strongly than parents' education; and within the parents' education, fathers' education was more related to achievement than mothers' education.

Gender differences

Table 3 shows the results of multiple regression analysis in which students' achievement was regressed on their maths self-concept, country, the interaction between maths self-concept and country, mothers' education, fathers' education and the number of books at home, splitting the U.S.–Japan combined sample by gender. Compared to the male sample, the female sample had larger standardised coefficients for maternal education, the interaction between students' maths self-concept scores and country, books and paternal education, while the female sample had the smaller standardised coefficients for maths self-concept. In particular, there

[5] R^2 is a measure to explain how well a regression line fits real data. The scale of R^2 is from 0 to 1.

Table 3 Effect of eighth-grade students' maths self-concept, country, mothers' education, fathers' education and number of books at home on students' achievement scores in maths for females and males (American and Japanese samples combined)

Independent variables	Female (n = 3,448)			Male (n = 3,531)		
	Unstandardised regression coefficient	Standard error	Standardised regression coefficient	Unstandardised regression coefficient	Standard error	Standardised regression coefficient
Maths self-concept	3.68**	.23	.26	3.92**	.25	.27
Country (Japan = 1)(U.S. = 0)	27.34**	8.42	.16	23.85*	9.34	.13
Interaction between country (Japan) and maths self-concept	3.11**	.43	.34	2.65**	.45	.30
Mothers' education	8.60**	1.61	.09	4.50**	1.75	.04
Fathers' education	14.11**	1.56	.15	14.20**	1.70	.14
Books	15.48**	.92	.24	13.54**	.96	.21
R^2	.42			.37		

* $p < .05$; ** $p < .01$

Source Data selected from *TIMSS 2007 International mathematics report* (Mullis et al. 2008) for the purposes of this study

were larger gender differences in the mothers' education variable, suggesting that maternal education was a stronger predictor of female maths achievement scores than of male maths achievement scores.

Country differences

Table 4 shows the results of multiple regression analysis in which students' achievement was regressed on their maths self-concept, mothers' education, fathers' education and the number of books at home, splitting the sample between Japanese and American students. The regression analysis for Japanese students had a larger coefficient for maths self-concept, $b = 6.26$, $t(2,663) = 22.46$, $p < .01$, than the regression analysis for American students, $b = 3.82$, $t(4,526) = 23.74$, $p < .01$. Among students in the Japanese sample, the coefficient for the mothers' education variable was $b = 15.89$, $t(2,663) = 5.82$, and for the fathers' education variable it was $b = 25.11$, $t(2,663) = 10.28$. These coefficients were also larger than the American sample coefficients for the mothers' education variable, $b = 5.07$, $t(4,526) = 3.93$, and the fathers' education variable, $b = 10.83$, $t(4,526) = 8.47$. In contrast, the coefficient for the books variable within the Japanese sample, $b = 11.5$, $t(2,663) = 10.21$, was smaller than the coefficient, $b = 16.05$, $t(4,526) = 19.93$, within the American sample.

Racial differences

To explore the racial differences within the American sample, each racial group was dummy-coded (for example, Black was coded 1 while other races were coded 0). Then American students' maths achievement was regressed on their maths self-concept, race, the interaction between race and maths self-concept, mothers'

Table 4 Effect of eighth-grade students' maths self-concept, country, mothers' education, fathers' education and number of books on students' achievement scores in maths for Americans and Japanese

Independent variables	American (n = 4,531)			Japanese (n = 2,668)		
	Unstandardised regression coefficient	Standard error	Standardised regression coefficient	Unstandardised regression coefficient	Standard error	Standardised regression coefficient
Maths self-concept	3.82**	.16	.30	6.26**	.27	.37
Mothers' education	5.07**	1.29	.06	15.89**	2.73	.11
Fathers' education	10.83**	1.28	.14	25.11**	2.44	.19
Books	16.05**	.81	.28	11.50**	1.13	.17
R^2	.28			.31		

* $p < .05$; ** $p < .01$

Source Data selected from *TIMSS 2007 International mathematics report* (Mullis et al. 2008) for the purposes of this study

education, fathers' education and the number of books at home. In each regression analysis, all races were included in the sample, but only one race was coded 1 while other races were coded 0.

Among different racial categories, a significant level ($p < .05$) of interaction between race and maths self-concept was found only when Whites ($n = 2{,}611$) and Blacks ($n = 523$) were dummy-coded as 1. The interaction between race and maths self-concept coefficient in the White students' sample was positive, $b = .75$, $t(4{,}510) = 2.43$, $p < .05$, and the interaction between race and maths self-concept in the Black students' sample was negative, $b = -1.48$, $t(4{,}510) = -3.13$, $p < .01$. These interactions between race maths self-concept coefficients suggested that White students were likely to have a lower maths self-concept but higher achievement while Black students tended to have a higher self-concept but lower achievement.

In sum, in the U.S.–Japan combined sample, research uncovered that eighth graders' maths scores were positively associated with their maths self-concept, fathers' education, mothers' education and the number of books at home. The standardised coefficients of the interaction between maths self-concept and country and maths self-concept were larger than the standardised coefficients of fathers' education, mothers' education and the number of books at home in this sample. Additionally, female students had a significantly larger standardised coefficient of the mothers' education variable than male students. Japanese students had larger standardised coefficients of maths self-concept, mothers' education and fathers' education variables than American students, but a smaller standardised coefficient of the number of books at home variable. Within the American sample, a coefficient of the interaction between maths self-concept and race was positive when White students were dummy-coded as 1 but negative when Black students were dummy-coded as 1.

Discussion

The relationship between maths self-concept and achievement

Overall, it was discovered that students' mathematical self-concept was positively related to their maths achievement both in the U.S. and in Japan. These results supported the hypothesis that students' self-confidence, self-motivation, and cognition of mastering a subject is positively related to students' maths achievement. Also, the results showed the existence of cultural differences in terms of how students' maths self-concept was related to their achievement. Japanese students were likely to have a lower self-concept than American students even when the students from the two countries had the same level of achievement. These results suggested that culture does influence the relationship between students' maths self-concept and their achievement. One possible reason why Japanese students had a lower self-concept may be that they compared their academic self-concept with that of other Japanese students. Japanese students were likely to compare their maths abilities with those of other Japanese students whose average maths scores were

higher than the international average. By comparing their maths scores with the Japanese national average, Japanese students could conclude that they were not good at maths. These findings supported Wilkins' (2004) study which found a positive association between students' maths self-concept and their achievement at the individual level but also showed that Asian students had lower mean academic self-concept in comparison with American students.

Among the variables used in the current research, the standardised coefficient of the interaction between maths self-concept and country was the largest, which implied that the joint effects from the two variables were stronger than other variables. Additionally, the standardised coefficient of a student's maths self-concept was more closely related to achievement than to the education level of his or her parents and the number of books kept at his or her household. It is suggested that how a student recognises his or her own maths ability was a better predictor for his or her achievement than other tangible factors.

Parental level of education was positively associated with achievement. However, standardised coefficients revealed that the paternal education variable was larger than the maternal education variable. To examine parents' education further, students' achievement was regressed in relation to fathers' and mothers' education using American and Japanese samples separately, as shown in Table 5. In both countries, fathers' education showed a stronger relationship with achievement than mothers' education. Additionally, the Japanese standardised coefficient of fathers' education, $b = .28$, $t(2{,}715) = 13.64$, $p < .01$, was larger than the American one, $b = .23$, $t(4{,}701) = 12.95, p < .01$, though the standardised coefficients of mothers' education in the Japanese sample, $b = .16, t(2{,}715) = 7.74, p < .01$, and the American sample, $b = .15, t(4{,}701) = 8.41, p < .01$, were almost the same. The results suggested that, looking at parental education, Japanese paternal education was likely to be related with achievement more strongly than American paternal education, and Japanese and American maternal education.

Table 5 Effect of eighth-grade students' mothers' education and fathers' education on students' achievement scores in maths for Americans and Japanese

Independent variables	American (n = 4,701)			Japanese (n = 2,716)		
	Unstandardised regression coefficient	Standard error	Standardised regression coefficient	Unstandardised regression coefficient	Standard error	Standardised regression coefficient
Mothers' education	11.67**	1.39	.15	23.21**	3.00	.16
Fathers' education	17.71**	1.37	.23	36.12**	2.65	.28
R^2	.11			.15		

** $p < .01$

Source Data selected from *TIMSS 2007 International mathematics report* (Mullis et al. 2008) for the purposes of this study

Gender differences

Table 3 shows how the coefficients changed when the sample was sorted by gender. In the table, the coefficient of the mothers' education variable in the female sample was almost twice as large as in the male sample. This pattern shows that maternal education was a stronger predictor of females' maths achievement scores than males' maths achievement scores. The fathers' education variable's unstandardised coefficient was stronger in the male sample than the female sample, but the results were opposite with the standardised coefficients. These results suggested that unlike boys, girls were more likely to be affected by the parent whose gender was identical with theirs.

The larger coefficients of the interaction between maths self-concept and country, books and country variables implied that they were better predictors of students' maths achievement in the female sample than the male sample. By contrast, girls' maths self-concept and fathers' education variables were slightly lower than those of boys, suggesting that these two variables were relatively weaker predictors of girls' maths achievement.

Country differences

When the sample was split by country, the Japanese maths self-concept coefficient was higher than the American one (Table 4). This result reflected the correlation between maths self-concept and achievement: Japanese had a stronger correlation ($r = .44$) than Americans ($r = .35$). Thus, a one-unit increase in the Japanese maths self-concept was more closely related to their own achievement than an increase in the American maths self-concept was related to American students' achievement. Additionally, the Japanese coefficients of mothers' education and fathers' education were higher than the corresponding American ones, while the American coefficient of books was higher than that of the Japanese. The results suggested that comparing the Japanese to the American sample, maternal and paternal education was a better predictor for Japanese students' achievement, but the number of books at students' households was better predictor for American students' achievement.

Racial differences

Using the racial information in the American sample, the same multiple regression analysis was applied, and the results are shown in Table 6 for White students and in Table 7 for Black students. Although the magnitudes were different, the interaction variable, which was made from dummy-coded information of race as White and Whites' maths self-concept, inferred that they had the same pattern as Japanese students by having a lower maths self-concept and higher achievement, $b = .75$, $t(4510) = 2.43$, $p < .05$. On the other hand, the interaction variable made from dummy-coded information of race as Black and Blacks' maths self-concept suggested that they tended to have a higher self-concept while they had lower achievement, $b = -1.48$, $t(4510) = -3.13$, $p < .01$. Peers could be one of the possible reasons for these differences; Whites were more likely to attend a school

Table 6 Effect of eighth-grade American students' maths self-concept, country, mothers' education, fathers' education and number of books on students' achievement scores in maths (Whites coded 1 in a race variable)

Independent variables	Unstandardised regression coefficient	Standard error	Standardised regression coefficient	*t* Value
Maths self-concept	3.51**	.23	.28	15.08
Race (White = 1)(Non-White = 0)	23.59**	7.03	.15	3.36
Interaction between race (White) and maths self-concept	.75*	.31	.12	2.43
Mothers' education	2.43*	1.24	.03	1.96
Fathers' education	9.70**	1.23	.12	7.9
Books	12.41**	.79	.22	15.68
N	4,517			
R^2	.34			

* $p < .05$; ** $p < .01$

Source Data selected from *TIMSS 2007 International mathematics report* (Mullis et al. 2008) for the purposes of this study

Table 7 Effect of eighth-grade American students' maths self-concept, country, mothers' education, fathers' education, and number of books on students' achievement scores in maths (Blacks coded 1 in a race variable)

Independent variables	Unstandardised regression coefficient	Standard error	Standardised regression coefficient	*t* Value
Maths self-concept	4.13**	.16	.33	25.12
Race (Black = 1) (Non-Black = 0)	−25.72*	10.89	−.11	−2.36
Interaction between race (Black) and maths self-concept	−1.48**	.47	−.15	−3.13
Mothers' education	6.07**	1.24	.08	4.91
Fathers' education	10.89**	1.23	.14	8.88
Books	13.65**	.78	.24	17.49
N	4,517			
R^2	.34			

* $p < .05$; ** $p < .01$

Source Data selected from *TIMSS 2007 International mathematics report* (Mullis et al. 2008) for the purposes of this study

where peers achieved higher, and they tended to have a lower estimation of their own maths capabilities compared to other students in the same school.

Differences between Japanese and Asian Americans were also explored to see cultural differences within the Asian racial category by using the same multiple regression model. However, due to the relatively small sample size of Asian American ($n = 128$) students, the interaction variable made from the racial information of Asian Americans and their maths self-concept did not reach a

significant level ($p = .08$). The correlation between Asian American maths self-concept and Asian American achievement was .29 while Japanese maths self-concept and Japanese achievement was .44, which inferred that Japanese students had a better calibration of their achievement. The gap between the two correlations suggested that the magnitudes of the relationship between maths self-concept and achievement may not function in the same way even if their race is same.

There were limitations in this study. First, there is an imbalance of accuracy among variables used in this study; one unit of maths self-concept variable may not have had the same level of accuracy as other variables due to its intangible characteristics. Second, this study was not able to address how racial differences functioned in the relationship between maths self-concept and achievement in the U.S. except for the White and Black samples. The other racial samples became smaller when the American sample was sorted into smaller groups depending on students' race. Third, the relationship between maths self-concept and other subjects was not explored. Although the cultural connection with self-concept found in this study could be counted as a part of the multidimensionality of self-concept, further research should be carried out to examine whether Marsh's I/E model needs to be changed in an international setting. Fourth, the influence of a country's economy and educational system was not considered. In future research, these elements could be included in independent variables.

Summary and implications

In this study, the relationship between eighth graders' maths self-concept and maths achievement was examined using TIMSS 2007 data which compared Japanese and American students. Mothers' education, fathers' education and the number of books held in students' households were used as independent variables. The results supported the positive association between students' maths self-concept and their maths achievement in both the Japanese and the American samples. However, Japanese students' self-concept was found to be lower than American students', even when they had the same level of achievement. Mothers' education, fathers' education and books were positively associated with students' achievement as well. Standardised coefficients suggested the stronger impact of the interaction between maths self-concept and country. This indicated that cultural differences between Japan and the U.S. could mediate the relationship between maths self-concept and maths achievement scores. An educator could consider that the relationship between students' maths self-concept and their achievement might not work in the same way if they had different cultural backgrounds. Researchers could also consider ethnic differences of the relationship between maths self-concept and achievement between White and Black students.

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